DEVELOPMENT OF DIGITAL ENERGY METER FOR DOMESTIC APPLIANCES

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This thesis is submitted as partial fulfillment of the requirements for the award of the
Bachelor of Electrical Engineering (Power System)

Faculty of Electrical & Electronics Engineering
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NOVEMBER, 2009

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"

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ACKNOWLEDGEMENT

I would like to express my utmost gratitude to my supervisor, En Mohd Redzuan Ahmad. He has provided the essential guidance and advice throughout the implementation of this project.

I also would like to thank all my beloved friends especially Mohd Rusdi and Muhammad Husni for their support and help. Their suggestions and ideas had in many occasions help to solve many of my problems.

Last but not least, I would like to express my appreciation to the various organizations and those who had directly and indirectly contributed towards the completion of this project.

ABSTRACT

An energy meter is a device that able to measure electric energy at any one time. The energy data is very important for the study about energy demand especially in residential sector. The meters that can be found in the market nowadays are expensive because they work on operation principle that requires the use of expensive hardware. Hence, a digital meter that can measure electrical energy consumed by domestic appliances such as kettle, television, toaster, and others has been developed. This meter is robust, user friendly and informative enough for the purpose of simple data gathering. The project involved of hardware designing and microcontroller interfacing. In hardware design, the energy will be determined in digital form. The function of the microcontroller is for the output part. It consists of soft code specially written to calculate energy cost and to convert digital energy signals to binary code decimal. The total energy consumption used by the appliances and the related cost are given as seven segment display after decoding.

ABSTRAK

Meter tenaga adalah satu peranti yang boleh mengukur tenaga pada bila-bila masa. Data tenaga tersebut amatlah penting untuk kajian mengenai permintaan tenaga terutama dalam sektor rumah kediaman. Meter yang boleh didapati ketika ini adalah terlalu mahal kerana ia bekerja mengikut prinsip operasi yang memerlukan penggunaan perkakasan yang mahal. Sehubungan itu, meter digital yang boleh mengukur peggunaan tenaga elektrik peralatan domestik seperti cerek elektrik, televisyen, pembakar roti dan sebagainya telah dibina. Meter ini tahan lasak, mesra pengguna dan memberi maklumat yang cukup untuk pengumpulan data yang ringkas. Projek ini melibatkan kerja merekabentuk perkakasan serta pengantaramuka pegawal terbenam. Di dalam merekabentuk perkakasan, kesan tenaga terpakai akan diperolehi dalam bentuk digital. Fungsi pengawal terbenam pula ialah untuk bahagian keluaran. Ia mengandungi pengaturcaran kod tertentu yang digunakan untuk mengira kos tenaga dan untuk menukar isyarat digital tenaga kepada nombor perpuluhah dalam kod binary. Oleh itu jumlah penggunaan tenaga sesuatu peralatan yang telah digunakan serta kosnya akan terpapar di tujuh pamer ruas selepas pengkodan.

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LIST OF ABBREVIATIONS

RM	-	Ringgit Malaysia
RMS	-	Root mean square
V	-	Voltage
I	-	Current
KWh	-	Kilowatt-hour
Hz	-	Hertz
S	-	Apparent power
P	-	Active power
Q	-	Reactive power
IC	-	Integrated circuit
ADC	-	Analog to digital converter
A/D	-	Analog to digital
DIP	-	Dual in line package
SOIC	-	Small outline integrated circuit
SSOP	-	Shrink small outline package
MCU	-	Microcontroller unit
HPF	-	High pass filter
CT	-	Current transformer
Max	-	Maximum
CMOS	-	Complementary metal-oxide semiconductor
TTL	-	Transistor/transistor logic
RAM	-	Random-access memory
ROM	-	Read-only memory

EEPROM	-	Electrical erasable programmable ROM
LED	-	light emitting diode
DC	-	Direct current
AC	-	Alternating Current
IEC	-	International Electrotechnical Commission
IEEE	-	Institute of Electrical and Electronics Engineers
ANSI	-	American National Standards Institute
TNB	-	Tenaga Nasional Berhad
$\sum$	-	Summation
$\int$	-	integrate
θ	-	Voltage phase angle
ψ	-	Current phase angle

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CHAPTER 1

INTRODUCTION

1.1 Project background

If you want to save power and reduce costs, you need to know how much power each appliance uses over a period of the time. Most appliances don’t run all the time, so you need to know the power they use while they are actually running and how much they use over the longer them. The easiest way to determine that is to use an electronic power meter and this new "Energy Meter" fits the bill nicely. It displays the measured power in Watts, the elapsed time and the total energy usage in kWh. In addition, it can show the energy cost in Ringgit Malaysia and cents. As a bonus, it also includes comprehensive brownout protection. Brownout is the low voltage condition that can be present even for several hours. This is often created when the power demand exceeds the capacitor of the power generator. Brownout can also cause many problems. Fortunately, high or low voltage problems can be tackled by using some good quality voltage regulators.

One obvious use for the this unit is to show refrigerator running costs over a set period of the time, so that you can quickly determine the effect of the different thermostat settings. Alternatively it could be used to show the different in energy consumption between the summer months and the winter months.

If you have a solar power installation, this unit will prove invaluable. It will quickly allow you to determine which appliances are the most ‘power hungry’, so that you can adjust your energy usage patterns to suit to capacity installation. And there are lots of other uses, for example the unit could be used to determine the cost pumping water, the running costs of the aquarium or even the cost of keeping your TV set on standby power, so that it can be switched on via the remote control.

1.2 Objective

The main objective of this project is to design and construct a digital energy meter for domestic appliances. This meter will measure the electrical energy digitally, so user can easily identify how much energy they used at one time.

1.3 Scope of Project

Since the energy meter can measure or determine the energy consumption of several appliances such as air-conditioners, refrigerators, washing machines, vacuum cleaners, and standby power for any house types in Malaysia, the data can be used for the following studies:

a) Determination of the average electrical energy consumption of selected appliances used in residential sector
b) Investigation of the impact of energy efficiency labeling of domestic appliance
c) Forecast of future energy demand in residential sector based on end-use modeling techniques.
d) Development of special website/programmers that can teach and promote efficient and wise use of energy.

1.4 Literature Review

The most common unit of measurement on the electricity meter is the kilowatt hour, which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules. Some electricity companies use the SI Mega joule instead.

Demand is normally measured in watts, but averaged over a period, most often a quarter or half hour. Reactive power is measured in "Volt-amperes reactive", (varh) in kilovar-hours. A "lagging" or inductive load, such as a motor, will have negative reactive power. A "leading", or capacitive load, will have positive reactive power.

Volt-amperes measures all power passed through a distribution network, including reactive and actual. This is equal to the product of root-mean-square volts and amperes.

Distortion of the electric current by loads is measured in several ways. Power factor is the ratio of resistive (or real power) to volt-amperes. A capacitive load has a leading power factor, and an inductive load has a lagging power factor. A purely resistive load (such as a filament lamp, heater or kettle) exhibits a power factor of 1. Current harmonics are a measure of distortion of the wave form. For example, electronic loads such as computer power supplies draw their current at the voltage peak to fill their internal storage elements. This can lead to a significant voltage drop near the supply voltage peak which shows as a flattening of the voltage waveform. This flattening causes odd harmonics which are not permissible if they exceed specific limits, as they are not only wasteful, but may interfere with the operation of other equipment.

Harmonic emissions are mandated by law in EU and other countries to fall within specified limits. In addition to metering based on the amount of energy used, other types of metering are available. Some meters measured only the length of time for which current flowed, with no measurement of the magnitude of voltage or current is being made. These were only suited for constant load applications. Neither type is likely to be used today. Some newer electricity meters are solid state and display the power used on an LCD, while newer electronic meters can be read automatically.

Plug in electricity meters (or "Plug load" meters) measure energy used by individual appliances. The meter is plugged into an outlet, and the appliance to measure is plugged into the meter. Such meters can help in energy conservation by identifying major energy users, or devices that consume excessive standby power. Examples of plug in meters include various Kill A Watt, Plug wise[2], and Watts Up[3] Meters.

A potentially powerful means to reduce household energy consumption is to provide real-time feedback to homeowners so they can change their energy using behavior. Recently, low-cost energy feedback displays, such as The Energy Detective, Eco-eye[7], wattson,[8], PowerWatch[9], or Cent-a-meter, have become available. A study using the similar PowerCost Monitor[10] deployed in 500 Ontario homes by Hydro One showed an average 6.5% drop in total electricity use when compared with a similarly sized control group. *Hydro One* subsequently offered free power monitors to 30,000 customers based on the success of the pilot.[11]

1.5 Report Outline

The report is organized into six chapters. The brief outline of each chapter is presented below:

Chapter 1 introduces the readers on usage and advantages of using this meter. The main objective and the scope of the project are also presented in this chapter.

Chapter 2 contains the study on the electrical energy and power. Some figure and equation are included in the chapter to enhance the understanding of readers on the energy meter operation.

Chapter 3 explains about the control element circuit for Digital Energy Meter Features, software and hardware implementation.

Chapter 4 explains the overall methodology and approach to build the energy meter. In this chapter, readers will know the process to develop the energy meter.

Chapter 5 contains result and the discussion for this energy meter.

Chapter 6 contains conclusions and suggestion for future work.

CHAPTER 2

DIGITAL ENERGY METER

2.1 ELECTRICAL ENERGY AND POWER

2.1.1 **Introduction**

Generally, in many real world situations, power is the rate at which work is done according to the equation below. This theory is found by Sir Isaac Newton (1642 – 1727).

Power = Work/Time …………………………………..(2.1)

In electrical, the electrical power is power per one hour by using electric energy according to the equation below:

Energy = average power x time……………………….(2.2)

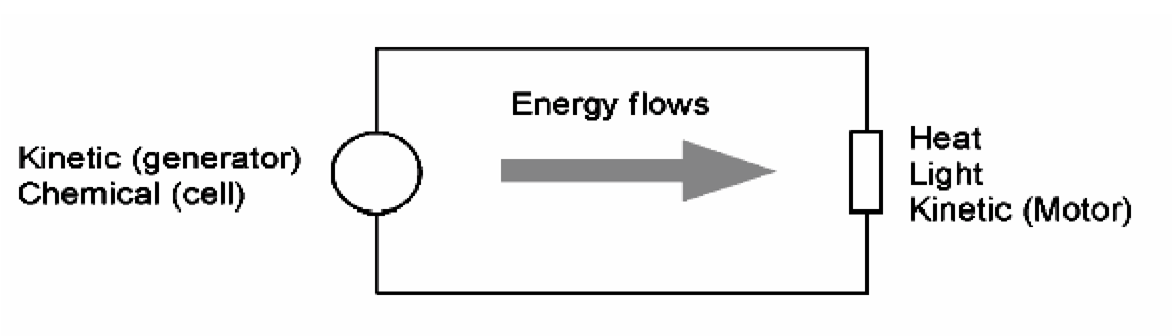

Figure 2.1: Energy Flows from Source to Load

Kinetic energy of the generator or chemical energy of the cell in Figure 2.1 is converted to electrical energy which flows through the circuit and is converted back to light, heat, and kinetic energy. Since energy is the product of power and time, the energy or watt-hour meter must take into consideration both of these factors. Basically, for this project, power relations are considered for measuring energy that produced by periodic currents and voltage.

2.1.2 Electrical Energy

Electric energy is the potential energy associated with the conservative Coulomb forces between charged particles contained within a system, where the reference potential energy is usually chosen to be zero for particles at infinite separation. It can be defined as the amount of work one must apply to charged particles to bring them from infinite separation to some finite proximity configuration. This is also equal to the negative of the work of the Coulomb forces that the particles exert on each other during the quasistWatic move.

$$U_E = W_{app} = -W_{\infty} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.3)$$

Where

- W_{app} is the work required to bring the system to a certain finite proximity configuration. "*app*" stands for applied, because this is work that must be applied to the system (or be supplied by another form of energy contained by the system) to configure it.
- W_{∞} is the work done by electrostatic inter-particle Coulomb forces during the move from infinity.

Sometimes people refer to the potential energy of a charge in an electric field. This actually refers to the potential energy of the system containing the charge and the *other* particles that created the electric field.[1]:§25-1

Furthermore, to calculate the work required to bring a charged particle into the vicinity of other particles, it is sufficient to know only the field generated by the other particles and the charge of the particle being moved. The field of the moving particle and the individual charges of the other particles do not need to be known.

Finally, it must be stressed that, even though this article talks about moving particles, the Coulomb force law on which this discussion is based only holds in the case of electrostatic systems. Therefore, any movement would have to be a quasistatic process.

2.1.3 The Type of Electrical Power

For general circuit, there are three types of power namely, real power, apparent power, and reactive power. The relation between these powers is shown in Figure 2.2 below.

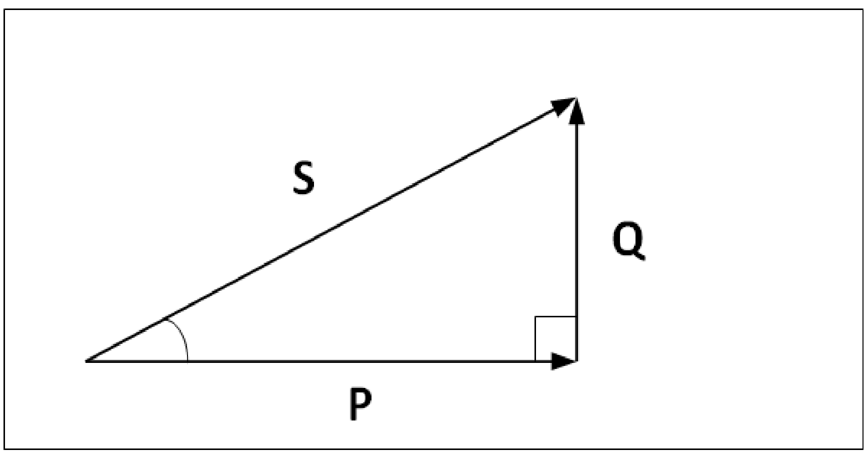

Figure 2.2: Power Triangle.

2.1.3.1 Apparent Power

The apparent power is the rate at which energy is absorbed by an element and the maximum real power that can be delivered to a load. It also varies as a function of time. As V_{RMS} and I_{RMS} are the effective voltage and current delivered to the load, the equation for the apparent power is shown below.

Apparent power, $S = V_{RMS} \times I_{RMS}$………………………...(2.4)

The correct implementation of the apparent energy measurement is bound by the accuracy of the RMS measurements.

The apparent power is an important quantity in engineering applications because its maximum value must be limited to all physical devices. For this reason, the maximum apparent or peak power is commonly used in specification of characterizing electrical devices. For instance, in an electronic amplifier, if the specified peak power at the input exceeded the limit power, the output signal will be distorted. So, the exceeding input rating may even damage the amplifier permanently. The apparent power is also known as the instantaneous power.

2.1.3.2 Reactive Power

The reactive power is defined in the IEEE Standard Dictionary 100-1996 as:

Reactive Power, $Q = \sum_{n=1} V_n I_n \sin \Phi_n$……………….(2.5)

Where V_n and I_n are respectively the voltage and current RMS values of the n^{th} harmonics of the line frequency, and Φ is the phase difference between the voltage